EFFECT OF PRE-AIMING APS LAUNCHER ON MINIMUM ENGAGEMENT RANGE AND MULTI-VEHICLE PROTECTION (U)

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ABSTRACT (U)

(U) In traditional Active Protection System (APS) modeling the countermeasure launcher is assumed to either be stowed under armor or at some fixed axis on the vehicle. The time required to detect the threat launch, raise and/or rotate the launcher, track the threat, and the fly-out of the countermeasure determines the minimum engagement range (shooter to victim). When operating in a cluttered battlefield, this may allow some threats to be inside this minimum range. However, by pre-aiming the launcher at the most likely, or most dangerous, location for an enemy to shoot from, a reduction in the minimum engagement range will be achieved.

(U) The risk in pre-aiming an APS launcher is twofold: You chose wrong and are shot from the blind side or you are attacked simultaneously, or nearly, from the "dangerous" side and the "safe" side. This can possibly be mitigated by one APS equipped vehicle concentrating on the high threat area while a second APS equipped vehicle protects both vehicles on the lower threat side. This paper will examine the minimum engagement range reduction achieved by a pre-aimed APS launcher and the feasibility of mutual protection.

(U) Introduction

(U) This paper will examine the utility of pre-aiming, i.e. pointing the radar/countermeasure launcher in the expected direction of attack. This pre-aiming is of benefit

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in countering the very short-range engagement or the very fast threats. Very fast threats such as kinetic energy rounds will not be considered here.

(U) The second portion of this paper will examine the ability of one vehicle to protect another vehicle with its Active Protection System (APS) from a moderate distance. This addresses the inherent risk in choosing the wrong direction for pre-aiming in the short-range engagement.

(U) The Threats

(U) The first threat for this study is a generic Rocket Propelled Grenade (RPG). The RPG's flight profile is:

1. Launch at an initial velocity of 135 meters/second;
2. Coast to a distance of 20 meters (approximately 0.15 seconds)
3. Ignite the flight motor and accelerate to 300 meters/second at a total distance from the launcher of 70 meters (approximately 0.38 seconds from launch to flight motor burnout).[1]

(U) The second threat is the AT-4. This is the US military's standard light anti-armor weapon. It has a muzzle velocity of 285 meters/second. [2]

(U) The Active Protection System

(U) The APS is a notional system consisting of a warning system, a slewed tracking radar, a slewed countermeasure launcher and the countermeasure rocket. The function of the warning system is to detect the launch of the threat, identify the threat, and provide the countermeasure launcher and radar with the correct azimuth bearing. Upon receiving the threat bearing, the radar and launcher will rotate to the proper azimuth, the radar will acquire and track the threat and generate a fire control solution. The launcher will then complete the final aiming and fire. The actual kill mechanism of the countermeasure is not defined here but it is assumed to be able to function at any desired distance from the host vehicle.

(U) For purposes of this study, the timeline will start the moment the threat leaves the launcher. The threat detection, identification and azimuth bearing determination will have occurred during the launch phase. However, the Radar/Launcher does not start its rotation until the threat has left its launcher.

(U) The acceleration rates of the radar/launcher for this study are 5,000, 7,500 and 10,000 degrees/second^2. The various azimuth angles that the radar/launcher will be rotated through will be 15, 45, 90, 135 and 180 degrees. Table I gives the slew times and the time reduction vs 180^o, which is the percent reduction in slew time compared with slewing from 180^o.

Table I. (U) APS Radar/Launcher Slew Rates

Acceleration (deg/sec^2)	Angle (degrees)	Slew Time (Seconds)	Time Reduction vs 180°
5,000	15	0.110	71.1%
5,000	45	0.190	50.0%
5,000	90	0.268	29.2%
5,000	135	0.329	13.4%
5,000	180	0.379	0.0%
7,500	15	0.089	71.1%
7,500	45	0.155	50.0%
7,500	90	0.219	29.2%
7,500	135	0.268	13.4%
7,500	180	0.310	0.0%
10,000	15	0.077	71.1%
10,000	45	0.134	50.0%
10,000	90	0.190	29.2%
10,000	135	0.232	13.4%
10,000	180	0.268	0.00%

(U) Velocities and Accelerations

(U) The individual acceleration rates of the RPG and the various interceptors is taken as a constant. In other words, the acceleration of a 400-g countermeasure does not change during the course of the motor firing. While this is not normally true, except in the case of impulse thrusters, this was chosen due to the notional nature of both the countermeasures and the RPG threat.

(U) In a similar vein, the effects of air drag are discounted. In the study of minimum range interceptions, there are numerous scenarios in which both the RPG and interceptor both are still accelerating. The discounting of air drag also reduces the flight time of the threat and therefore increases the stress on the APS. For the longer-range engagements, it still benefits the threat because the relatively lighter RPG and AT-4 would lose velocity more quickly than the heavier interceptor.

(U) There are six different interceptors for this study. They were chosen in an attempt to bound the problem and cover a wide variety of possible interceptor performances. The interception ranges, 10, 15 and 20 meters are recognized as being extremely short but were selected on the assumption that the vehicle is in an ambush scenario and being fired upon from short range. The interceptor's performance and flight time to the various standoff ranges is given in Table II.

Table II. (U) Interceptor Velocities and Accelerations

Speed (m/s)	Acceleration (g)	Burnout distance (meters)	Burnout time (seconds)	Flight Time to 10 meters	Flight Time to 15 meters	Flight Time to 20 meters
250	300	10.63	0.085	0.082	0.103	0.123
300	300	15.31	0.102	0.082	0.101	0.118
400	400	20.41	0.102	0.071	0.087	0.101
500	500	25.51	0.102	0.064	0.078	0.090
600	500	36.73	0.122	0.064	0.078	0.090

(U) Determination of Closest Firing Position

(U) The closest firing distance is the sum of the distances that the threat travels during the radar/launcher slew phase (D_{slew}), the distance traveled during tracking phase (D_{track}), the distance traveled during the interceptor fly-out (D_{flyout}), and the standoff range ($D_{standoff}$). Mathematically:

$$\text{(U) Closest Firing Distance} = D_{slew} + D_{track} + D_{flyout} + D_{standoff}$$

(U) RPG Self-Protection

(U) In this section, self-defense against RPGs will be studied at standoff distances (vehicle to threat defeat) of 10, 15 and 20 meters.

(U) The results of this is presented in Table III. The "Percent Range Reduction" is the reduction in the closest possible interception distance of the pre-aimed launcher relative to the launcher required to rotate 180°. Observe that the values for the 500 meter/second and 600 meter/second interceptors are identical. This is due to their burnout distances being greater than the intercept range and having equal accelerations.

Table III. (U) Self-Protection Against RPG

Launcher Acceleration (deg/sec^2)/ Launcher Rotation (deg)	Interceptor Velocity (m/s)/Interceptor Acceleration (gees)	10 Meter Standoff		15 Meter Standoff		20 Meter Standoff	
		Closest Firing Position (meters)	Percent Range Reduction	Closest Firing Position (meters)	Percent Range Reduction	Closest Firing Position (meters)	Percent Range Reduction
5000/15		45	62%	55	58%	64	55%
5000/45		64	47%	74	43%	85	40%
5000/90		86	28%	97	26%	108	24%
5000/135		104	13%	115	12%	126	11%
5000/180		120	0%	131	0%	142	0%
7500/15		42	58%	50	54%	60	51%
7500/45		55	44%	65	41%	75	38%
7500/90	250/300	72	27%	83	25%	93	23%
7500/135		86	13%	97	11%	108	10%
7500/180		99	0%	110	0%	121	0%
10000/15		39	54%	48	51%	57	47%
10000/45		51	41%	60	38%	70	35%
10000/90		64	26%	74	24%	85	22%
10000/135		76	12%	86	11%	97	10%
10000/180		86	0%	97	0%	108	0%
5000/15		45	62%	54	58%	63	55%
5000/45		64	47%	74	43%	83	40%
5000/90		86	28%	97	26%	107	24%
5000/135		104	13%	115	12%	125	11%
5000/180		120	0%	130	0%	140	0%
7500/15		42	58%	50	54%	59	51%
7500/45		55	44%	65	41%	74	38%
7500/90	300/300	72	27%	82	25%	92	23%
7500/135		86	13%	97	11%	107	10%
7500/180		99	0%	109	0%	119	0%
10000/15		39	54%	48	51%	56	47%
10000/45		51	41%	60	38%	69	36%
10000/90		64	26%	74	24%	83	22%
10000/135		76	12%	86	11%	96	10%
10000/180		86	0%	97	0%	107	0%
5000/15		43	63%	51	59%	59	56%
5000/45		61	47%	70	44%	79	42%
5000/90		83	29%	93	26%	102	25%
5000/135		101	13%	111	12%	120	11%
5000/180		116	0%	126	0%	135	0%
7500/15		40	59%	48	55%	55	52%
7500/45		53	45%	61	42%	70	39%
7500/90	400/400	69	28%	78	26%	87	24%
7500/135		83	13%	93	12%	102	11%
7500/180		95	0%	105	0%	114	0%
10000/15		37	55%	45	51%	53	48%
10000/45		48	42%	57	39%	65	36%
10000/90		61	26%	70	24%	79	23%
10000/135		72	13%	82	12%	91	11%
10000/180		83	0%	93	0%	102	0%

Table III (Continued). (U) Self-Protection Against RPG

Launcher Acceleration (deg/sec^2)/ Launcher Rotation (deg)	Interceptor Velocity (m/s)/Interceptor Acceleration (gees)	10 Meter Standoff		15 Meter Standoff		20 Meter Standoff	
		Closest Firing Position (meters)	Percent Range Reduction	Closest Firing Position (meters)	Percent Range Reduction	Closest Firing Position (meters)	Percent Range Reduction
5000/15	500/500	42	63%	50	60%	57	57%
5000/45		59	48%	68	45%	76	42%
5000/90		81	29%	90	27%	99	25%
5000/135		99	13%	108	12%	117	12%
5000/180		114	0%	123	0%	132	0%
7500/15		38	59%	46	55%	53	52%
7500/45		51	45%	59	42%	67	40%
7500/90		67	28%	76	26%	84	24%
7500/135		81	13%	90	12%	99	11%
7500/180		93	0%	102	0%	111	0%
10000/15		36	55%	44	52%	51	48%
10000/45		47	42%	55	39%	62	37%
10000/90		59	27%	68	25%	76	23%
10000/135		70	13%	79	12%	88	11%
10000/180		81	0%	90	0%	99	0%
5000/15	600/500	42	63%	50	60%	57	57%
5000/45		59	48%	68	45%	76	42%
5000/90		81	29%	90	27%	99	25%
5000/135		99	13%	108	12%	117	12%
5000/180		114	0%	123	0%	132	0%
7500/15		38	59%	46	55%	53	52%
7500/45		51	45%	59	42%	67	40%
7500/90		67	28%	76	26%	84	24%
7500/135		81	13%	90	12%	99	11%
7500/180		93	0%	102	0%	111	0%
10000/15		36	55%	44	52%	51	48%
10000/45		47	42%	55	39%	62	37%
10000/90		59	27%	68	25%	76	23%
10000/135		70	13%	79	12%	88	11%
10000/180		81	0%	90	0%	99	0%

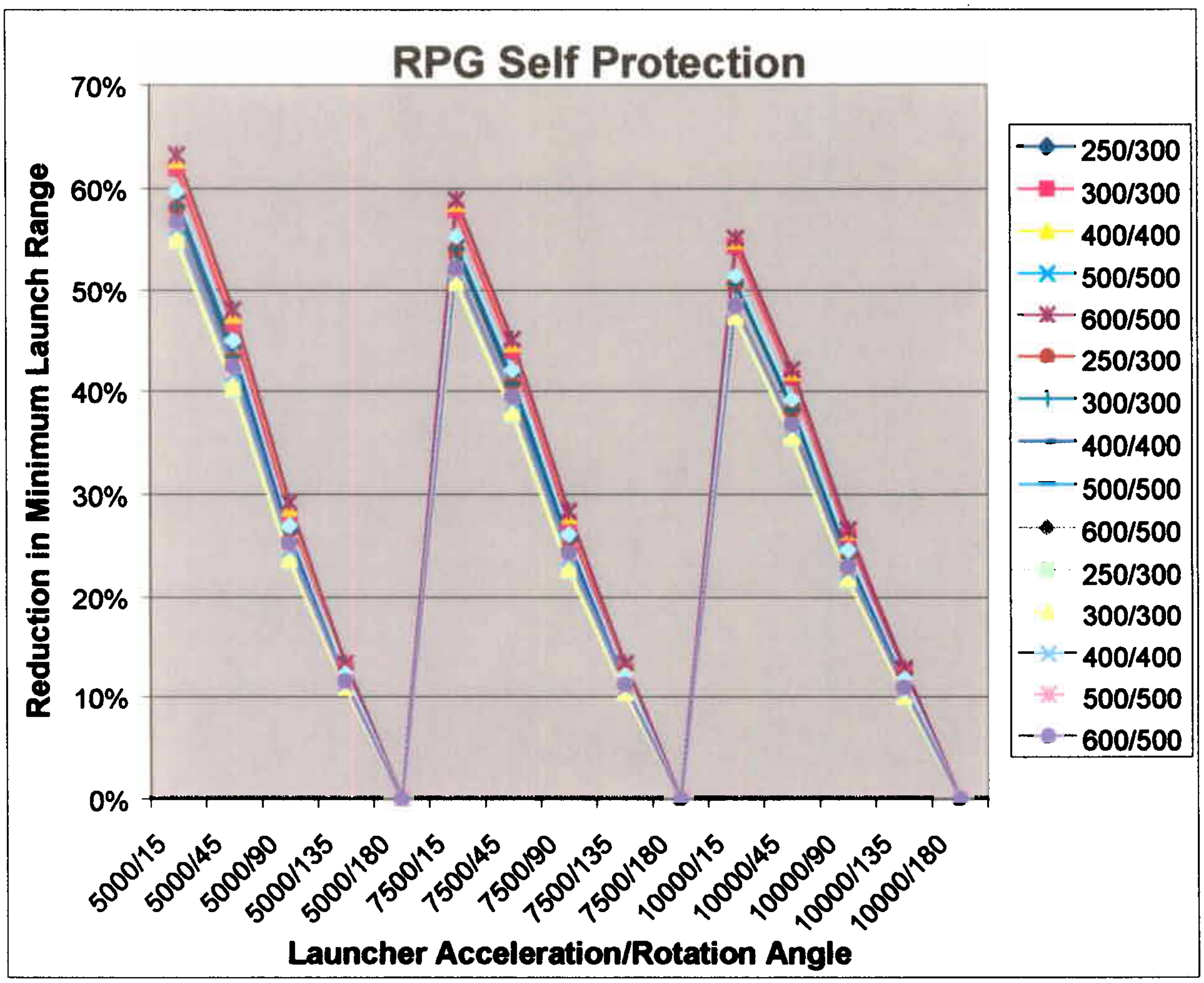

Figure 1. (U) RPG Self-Protection

(U) <u>AT-4 Self Protection</u>

(U) As the results for AT-4 Self-Protection are similar to the RPG Self-Protection, only a limited data set will be provided in this paper.

Table IV. (U) Self-Protection Against AT-4

Launcher Acceleration (deg/sec^2)/ Launcher Rotation (deg)	Interceptor Velocity (m/s)/Interceptor Acceleration (gees)	10 Meter Standoff		15 Meter Standoff		20 Meter Standoff	
		Closest Firing Position (meters)	Percent Range Reduction	Closest Firing Position (meters)	Percent Range Reduction	Closest Firing Position (meters)	Percent Range Reduction
5000/15	300/300	79	49%	89	46%	99	44%
5000/45		102	35%	112	33%	122	31%
5000/90		124	20%	135	19%	144	18%
5000/135		141	9%	152	9%	161	8%
5000/180		156	0%	166	0%	176	0%
7500/15		73	46%	84	43%	93	40%
7500/45		92	32%	102	30%	112	28%
7500/90		110	19%	120	18%	130	17%
7500/135		124	9%	135	8%	144	8%
7500/180		136	0%	146	0%	156	0%
10000/15		70	44%	80	40%	90	38%
10000/45		86	31%	96	28%	106	27%
10000/90		102	18%	112	17%	122	16%
10000/135		114	8%	124	8%	134	7%
10000/180		124	0%	135	0%	144	0%
5000/15	400/400	76	50%	85	47%	94	45%
5000/45		99	35%	108	33%	117	32%
5000/90		121	21%	131	20%	140	19%
5000/135		138	9%	148	9%	157	8%
5000/180		153	0%	162	0%	171	0%
7500/15		70	47%	80	44%	89	42%
7500/45		89	33%	98	31%	107	29%
7500/90		107	19%	117	18%	125	17%
7500/135		121	9%	131	8%	140	8%
7500/180		133	0%	142	0%	151	0%
10000/15		67	45%	76	42%	85	39%
10000/45		83	32%	92	29%	101	27%
10000/90		99	18%	108	17%	117	16%
10000/135		111	8%	120	8%	129	7%
10000/180		121	0%	131	0%	140	0%

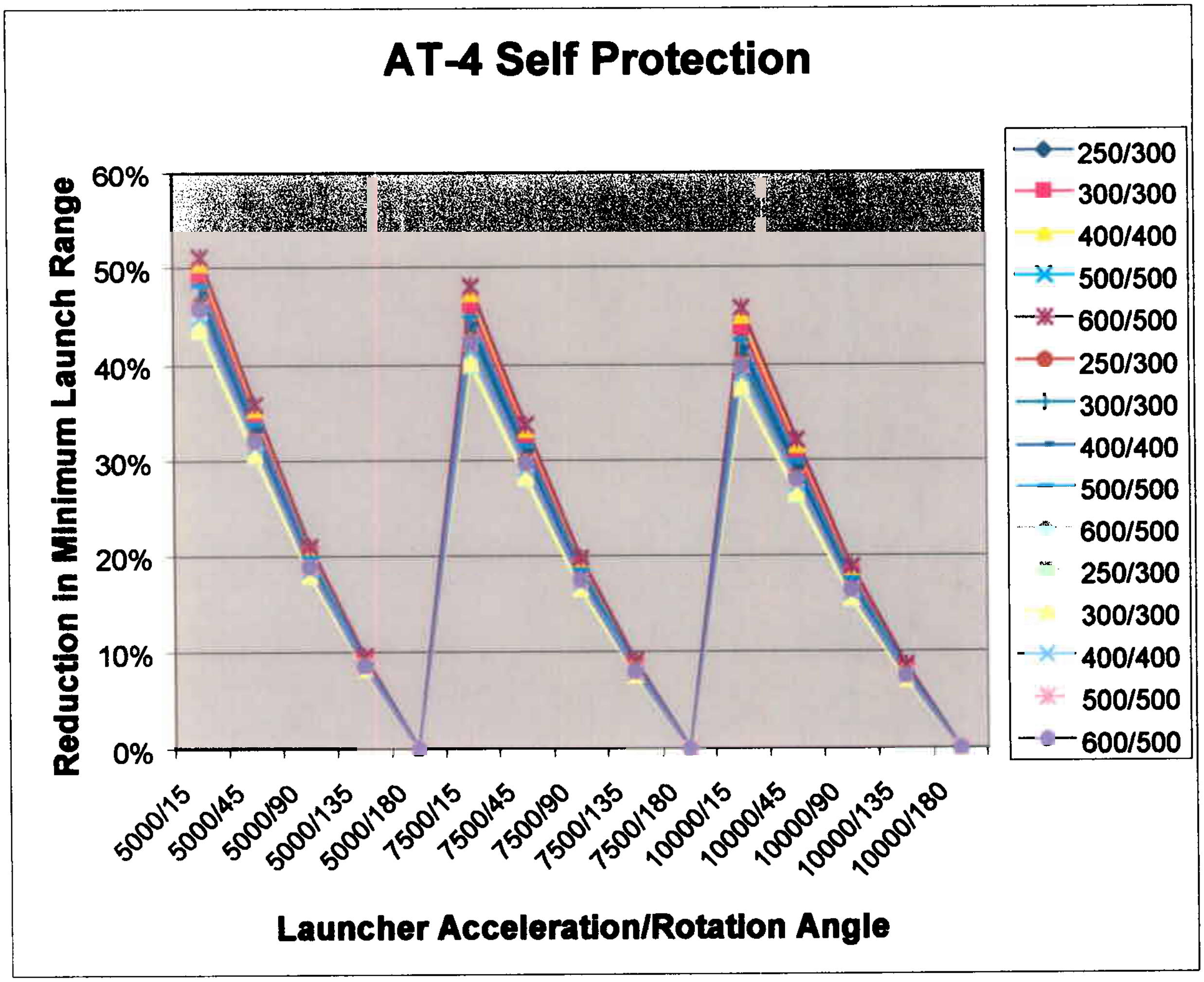

Figure 2. (U) AT-4 Self-Protection

(U) <u>Mutual Protection</u>

(U) In this section, the ability of one vehicle's APS to defend another will be analyzed. One of the inherent risks in pre-aiming an APS is: what happens if you choose wrong or your enemy shoots from both sides?

(U) In this scenario the two vehicles will be located at 25, 50 and 75 meters apart. The attack angle, ø, will be 90°. See Figure 3.

(U) RPG Mutal Protection

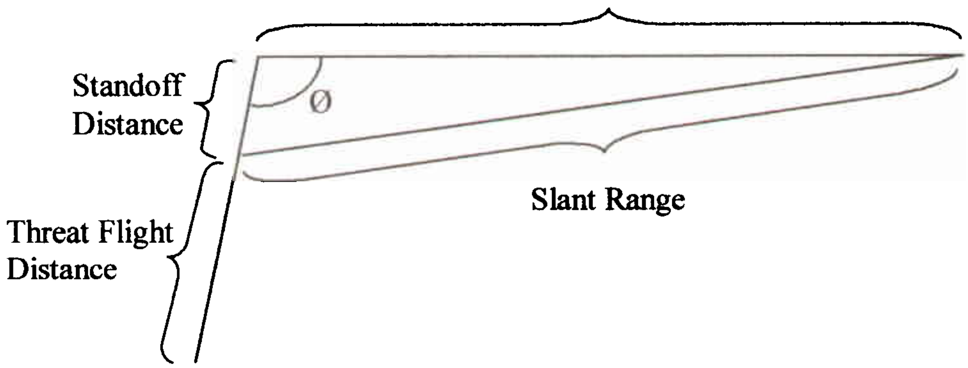

Figure 3. (U) Mutual Protection Engagement Geometry

(U) A major complication in protecting a second vehicle against the RPG threat is that the first vehicle's APS must wait until the RPG flight motor has finished burning in order to determine the velocity of the threat. This is necessary for the generation of a fire control solution. This will increase the minimum threat flight distance for the RPG by 70 meters.

(U) There is no consideration of the Radar/Launcher slew rates or rotation angles in this scenario due to the fact that the maximum slew period of 0.379 seconds (see Table I.) is less than the RPG flight motor burnout time. This then eliminates the variables slew rate and rotation angle from consideration.

Table V. (U) Mutual Protection Against RPG

Vehicle Separation (meters)	Interception Distance (meters)	Interceptor Velocity (m/sec)/Acceleration (g)				
		250/300	300/300	400/400	500/500	600/500
		Closest Firing Position From Protected Vehicles (meters)				
75	20	211	198	179	167	162
	15	205	192	173	161	157
	10	199	186	167	156	151
50	20	182	174	161	153	150
	15	175	168	154	147	144
	10	169	161	149	141	139
25	20	156	152	144	140	139
	15	148	144	137	133	133
	10	140	137	130	126	126

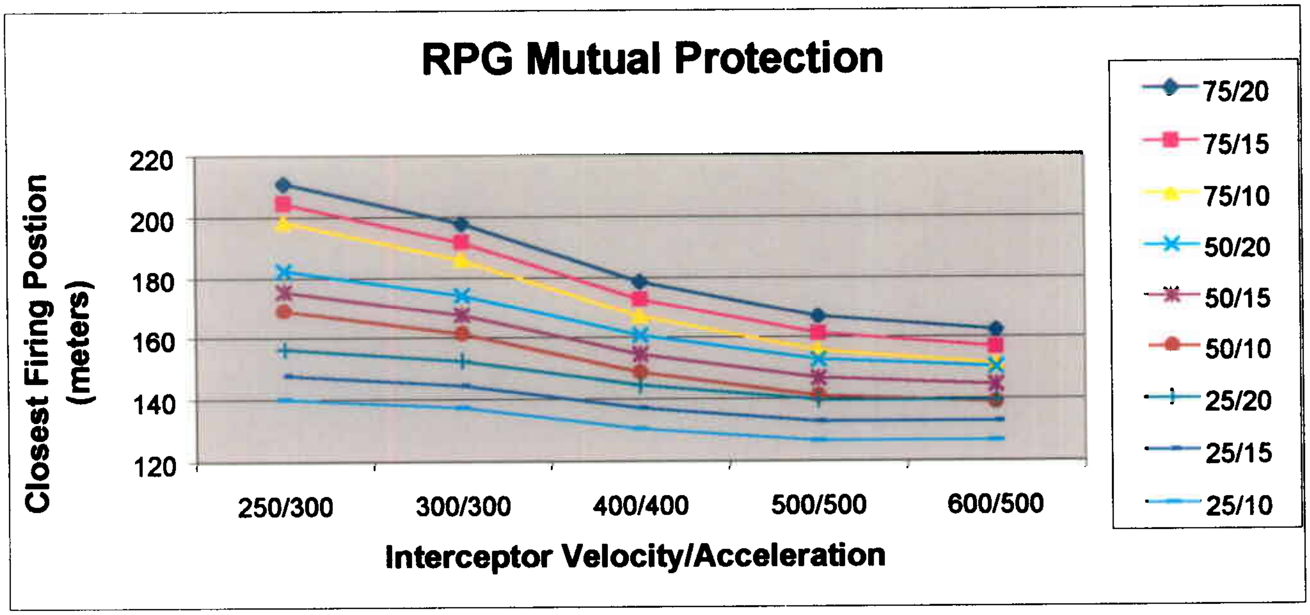

Figure 4. (U) RPG Mutual Protection

(U) AT-4 Mutual Protection

(U) Due to the large number of permutations (75), only two representative combinations of rotation angles and slew acceleration rates; 15° and 90° rotations and a 7,500 degree/second^2 will be show here.

Table VI. (U) Mutual Protection Against AT-4 – 15° Launcher Rotation

Vehicle Separation (meters)	Interception Distance (meters)	Interceptor Velocity (m/sec)/Acceleration (g)				
		250/300	300/300	400/400	500/500	600/500
		Closest Firing Position From Protected Vehicles (meters)				
75	20	160	148	130	119	114
	15	154	142	124	113	109
	10	148	136	118	107	103
50	20	133	125	113	105	103
	15	126	119	106	99	97
	10	120	113	101	93	91
25	20	108	105	97	93	71
	15	100	97	90	86	66
	10	93	90	83	80	61

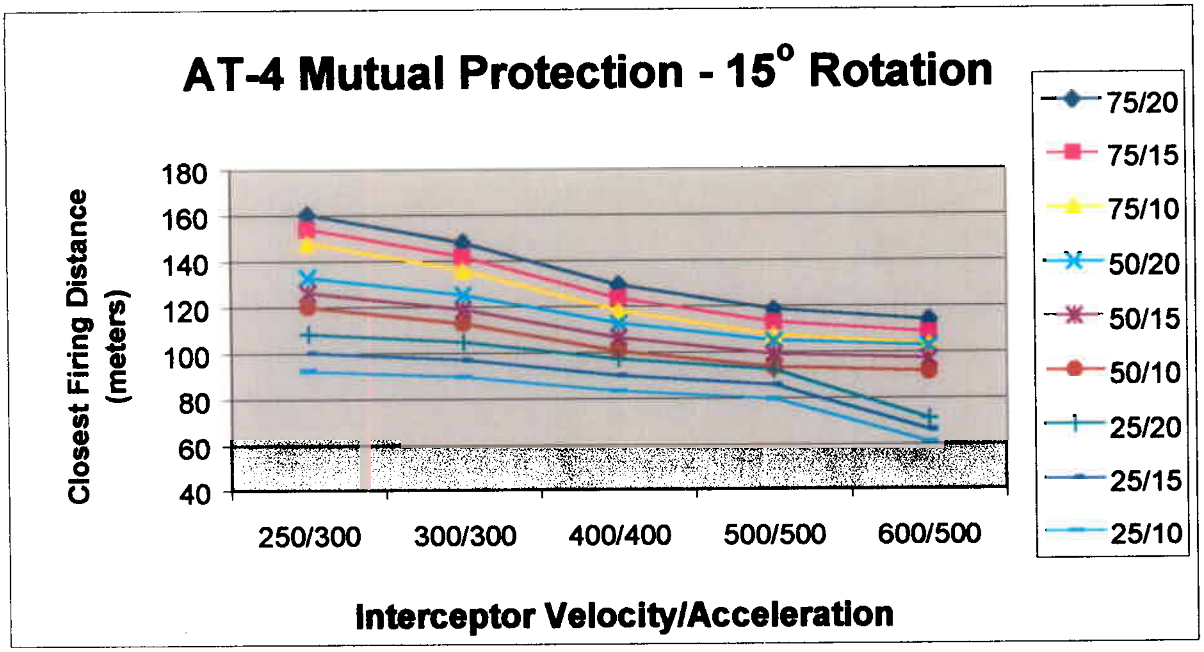

Figure 5. (U) AT-4 Mutual Protection – 15° Rotation

Table VII. (U) Mutual Protection Against AT-4 – 90° Launcher Rotation

Vehicle Separation (meters)	Interception Distance (meters)	Interceptor Velocity (m/sec)/Acceleration (g)				
		250/300	300/300	400/400	500/500	600/500
		Closest Firing Position From Protected Vehicles (meters)				
75	20	197	185	167	155	151
	15	191	179	161	150	145
	10	185	173	155	144	140
50	20	170	162	150	142	140
	15	163	156	143	136	134
	10	157	150	138	130	128
25	20	145	142	134	129	108
	15	137	134	127	123	103
	10	130	127	120	117	98

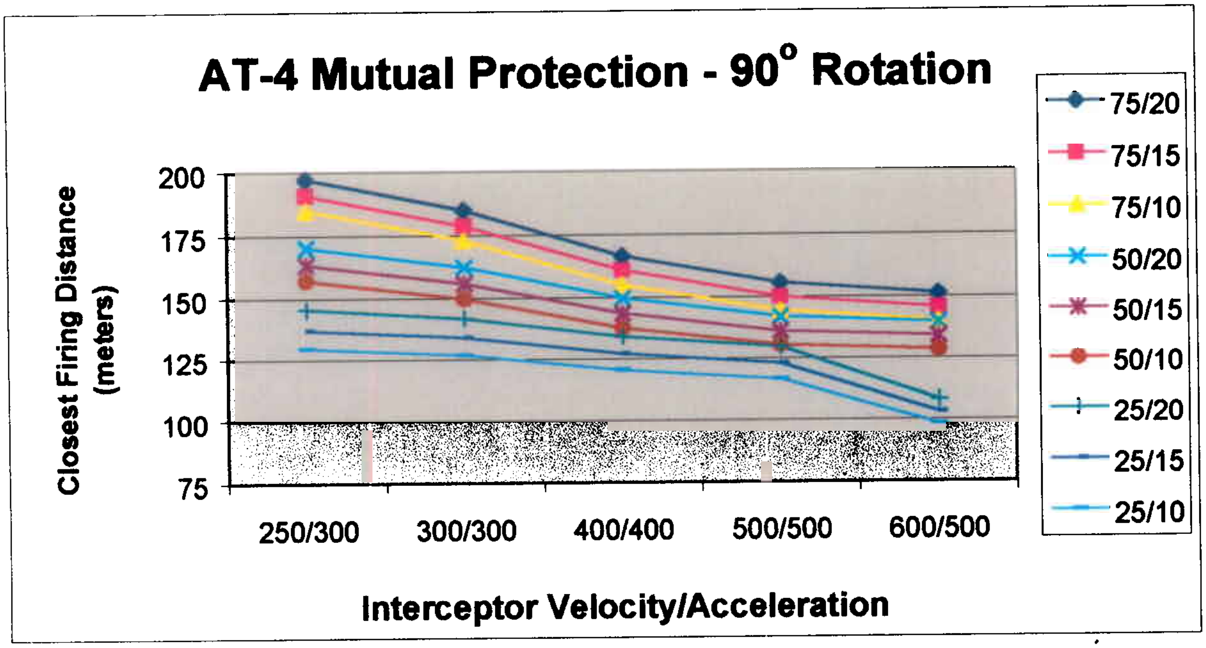

Figure 6. (U) AT-4 Mutual Protection – 90° Rotation

(U) Conclusions

(U) The value of pre-aiming the radar/countermeasure launcher has been shown to be of great value. Even when only within 45°, this can reduce the closest launch range by approximately 40%. This effect is greater for the systems with the lower slew acceleration rates and the slower interceptors.

(U) The concept of pre-aiming a weapon or in this case a countermeasure, in the direction of the probable enemy attack is a basic military doctrine. A tanker who does not keep his main gun, and therefore his heaviest armor, directed toward the enemy will not be in tanker business for very long.

(U) The ability to provide mutual self-protection against close-in threats is very limited. The vehicles would either be forced to be very close together, placing both vehicles in a possible ambush zone or the threats would have to be launched from well outside their usable range. When operating combat vehicles in possible ambush zones a secondary APS optimized for the extreme close-in ranges may be required. This system's complexity could be minimized by limiting it to the close-in threat.

(U) Mutual self-protection against longer range Anti-Tank Guided Missiles (ATGM) may however, be feasible. These threats are generally launched from a greater distance and are much larger than the RPG or AT-4. A very rough order-of-magnitude approximation shows that an ATGM with the same flight profile as the RPG could be intercepted by a 500 meters/second interceptor at 75 meters from the protected vehicle with a protector/protected distance of 1000 meters and a launch distance of 800 meters.

(U) The rather crude estimation from the pervious paragraph assumes a constant velocity for both the threat and interceptor, which at these ranges would obviously not be true. Such a system would undoubtedly be rather large and the interceptor would almost certainly require guidance, but it would allow one vehicle to protect many vehicles from long range ATGM threats. It also overstates the velocity of the threat; most ATGMs average velocity is on the order of 200 meters/second. [3]

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